Empire Magnetics Inc.

Motors That Survive

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Radiation-Hardened Motors

ORNL Develops Fuel Pin Dissolver with Empire's Radiation-Resistant Motors

Motion control in radiation-intensive environments poses a serious challenge to the design engineer. Conventional step and microstepping motors are susceptible to high-energy gamma radiation particles that will attack the motor materials. Usually, the organic compounds are most susceptible to breakdown by radiation, and as a result the lubricants, varnish, lamination bonding, and cable insulation in standard, commercially-available motors will all deteriorate over relatively short periods of time.

A new generation of radiation-resistant motors has been developed to greatly expand the design possibilities in highly radioactive environments. One new motor design was recently a part of a dissolver system designed by Oak Ridge National Laboratory (ORNL). The dissolver system is used to reprocess spent nuclear fuel.

A key step in the fuel recycling process is the separation of the spent fuel oxides from the stainless steel cladding by dissolving pieces or pellets in hot nitric acid. In this application, the motor provides the agitation necessary to speed the dissolving process.

The environmental factors, in addition to the functional requirements of this application, presented a significant challenge to the motion control engineers. The motor had to provide sufficient power and torque to move the load. The system also needed to have positional as well as velocity control, and had to be totally reliable, even when the assembly would be subjected to massive doses of radiation, heat, and nitric acid fumes. Replacement of components is expensive, but certain failure modes would be environmental disasters. As such, anything that could be done to lengthen useful life was considered a good investment, while avoiding catastrophic failure was critical.

After a considerable search, Oak Ridge was able to identify Empire Magnetics as the company that could provide radiation-resistant components closest to its requirements. Motors with 2×10^8 Rads TAD were already a part of Empire's product offering, but ORNL wanted to know if the company would be willing to push the technology to achieve 1×10^9.

An agreement was made to have Empire Magnetics provide motors on a "best effort" basis while ORNL would test them through the REACH program. Dr. Brad Weil would eventually oversee the testing program, and Dr. John Draper would cross-check the results. Extracts of their reports are shown as page inserts.

Empire provided stepper motors and brushless servo motors for testing purposes. In the final analysis, all of the Empire-supplied equipment was still functional when the testing was concluded due to budgetary constraints. By the end of the testing, some of the motors had been subjected to total accumulated doses in excess of 1x109 rads, others had reached 5x108 rads, depending on their location in the hot cell. All of the Empire supplied motors were tested for a long enough period to indicate that they would have lasted much longer had the test been continued.

Based on the results of the testing, Empire contracted to provide an assembly to drive the dissolver system. For this purpose, a stepper motor, cycloidal gearbox and resolver assembly were selected.

The assembly included an 87:1 gear ratio in an in-line arrangement. This mechanical arrangement allowed the use of a brushless resolver driven directly by the output shaft of the gear assembly. In this way, the absolute position of the output shaft could be tracked, and it would allow the operator to know the position of the shaft immediately upon power-up ... a very important feature to avoid accidentally dumping radioactive nitric acid solution. This same feature eliminated the mechanical errors of the motor and gearbox from the feedback loop.

The radiation-resistant stepper motor was powered by a bipolar chopper drive and controlled by a PC-based local controller. The resolver feedback was supported by an electronics card built by Empire, and Empire provided the complete subsystem consisting of the radiation-resistant motor, gearbox and resolver in an integrated mechanical assembly. This assembly was sealed and protected against the nitric acid fumes. The electronics package, along with the software, were a part of the subsystem, allowing Empire to provide a completely functional, tested subsystem that met all of the specifications.

The in-cell motor is controlled by a remote motor control station out-of-cell. The motor is driven by a bipolar chopping drive that is controlled by the motor control computer, which functions as a slave device and is intended to receive instructions from a host computer via a serial RS-232 communications link. The heart of the motor control computer is the indexer, which manages the basic motor motion profiles. Parameters such as distance, direction, speed and acceleration are set by forming command sequences of ASCII mnemonics. The command sequences define a motion profile and are programmed into the indexer via the serial communications link.

The subassembly had been integrated into the final machine, and has been in operation since April 1991. Empire has not been asked to make any service calls in all that time.

Here are excerpts from the original motor testing that was sponsored by the American Nuclear Society, from a paper by J.V. Draper, B.S. Weil and J.B. Chesser of the Robotics and Process Systems Division, ORNL:

"Four AC servo motors were tested on the hypothesis that motor performance would decline with the dose received because of degradation of stator coil insulation or motor bearings. The motor assemblies for each unit included (1) the motor, (2) a resolver, (3) a roller chain sprocket to provide an inertial load on the motors, (4) a motor support stand, (5) a thermocouple, (6) a servo motor amplifier, and (7) a resolver interface. Three motors were placed in the irradiation cell and one motor was placed outside the cell, along with all of the amplifiers and resolver interfaces. The AC servo motors experienced 1.03×10^5 R/h and received a total accumulated dose of 1.03×10^9 R. During each operating cycle, for each motor the DAS recorded output current from the motor amplifier, resolver position, and inertial load tachometer output. At the end of each operating cycle, it recorded the temperature of each motor.

"The AC servo motors remained in the irradiation cell for the length of the testing program but were not affected by the radiation. The motors seemed extremely robust and quite capable of operating under the radiation conditions imposed during testing."

Empire's radiation-resistant stepper motors were tested during the same period. The purpose of the testing was to determine whether the motors could survive a dose as high as 10^9 R. To quote from the above paper: "No changes in performance occurred during the irradiation testing, as far as could be determined ..."